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Indian Standard

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ऑनलाइन रिसाव सील प्रणाली — रीति संहिता

Online Leakage Sealing Systems — Code of Practice

ICS 21.020

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Fluid Power Systems Sectional Committee, PGD 36

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards after the draft finalized by the Fluid Power Systems Sectional Committee had been approved by the Production and General Engineering Division Council.

Process plant operations are continuous in nature. Leaks do happen through flange joints, weld joints or even pipe body itself. Such events call for immediate maintenance. Some of the leaks may call for complete depressurization of the system for maintenance depending on the risk they present. Minor leaks where the risks are low can be attended without depressurizing and isolating the plant or piping system. Such low risk cases can be considered for arresting through ‘on line leak sealing’ process and help to save operating losses of plants.

Online sealing is a technique in which leak in a pipeline or equipment is arrested by established industry practices which includes use of specially designed box clamps, split clamps, cold weld repair/wrapping, drilling injection, peening and sometimes pinching of small-bore components.

Use of box and split clamps involves installing a clamp around the leak location and filling up the space between the clamp and the leaking component with a thermosetting compound. Thermosetting compound as it is pumped into the clamp fills all the space/voids and then hardens. As it hardens and sets the leak is sealed.

The effectiveness of the online sealing process depends on the following major factors:

a) Extent of leak;
b) Nature of the leaking fluid;
c) Operating conditions of the leaking fluid (pressure, temperature);
d) Type of component that is leaking;
e) Clamp design and injection locations;
f) On site conditions — Scaffolding/Space constraints etc;
g) Sealing compound used; and
h) Skill of the personnel involved in the online sealing process.

The above factors bring along, a host of other unknown variables, and hence online sealing is always considered to be temporary repair and shall be restored to normalcy at the first available opportunity.

Several incidents have been reported in the industry during and after execution of online sealing jobs highlighting the need for stringent quality requirements during all phases of the activity.

This new development is undertaken in the light of experiences amassed by various end users and continuous improvements in the industry practices. The endeavour is also to align the practices in line with internationally accepted practices as well.

The formation of creating a new specification is undertaken in the light of experience and continuous development and to align with national and international practices wherever appropriate.

In the formulation of this standard, assistance has been taken from the following International Standards:

ISO 9924 (Part 1) : 2016	Rubber and rubber products — Determination of the composition of vulcanizates and uncured compounds by thermogravimetry — Part 1: Butadiene, ethylene-propylene copolymer and terpolymer, isobutene-isoprene, isoprene and styrene-butadiene rubbers
ASME BPVC-II-D : 2001	ASME Boiler and Pressure Vessel Code, Section II: Materials — Part D: Properties
ASME BPVC-VIII-1 : 2021	ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 Rules for Construction of Pressure Vessels.

(*Continued on third cover*)

Indian Standard

ONLINE LEAKAGE SEALING SYSTEMS — CODE OF PRACTICE

1 SCOPE

1.1 This standard gives requirements to users to ensure quality assurance during design, fabrication and safe installation of clamps and sealing components for online leak sealing.

1.2 This standard specifies the physical characteristics as well as physical/chemical requirements under a specific application condition.

1.3 This standard is complementary to the specific requirements during application appropriate to the technology and to protect the assets of the establishment and human life.

1.4 This standard is not meant for the article/items/equipment/consumables being used and become part of the operational system during and after on-line leak sealing services.

2 REFERENCES

The listed below standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on the standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below:

IS No.	*Title*
IS 814 : 2004	Covered electrodes for manual metal arc welding of carbon and carbon manganese steel — Specification (*sixth revision*)
IS 822 : 1970	Code of procedure for inspection of welds
IS 1179 : 1967	Specification for equipment for eye and face protection during welding (*first revision*)
IS 1448 (Part 87) : 1979	Methods of test for petroleum and its products: Part 87 Auto ignition temperature of liquid petroleum products
IS 2825 : 1969	Code for unfired pressure vessels
IS 5206 : 1983	Specification for covered electrodes for manual metal arc welding of stainless steel and other similar high alloy steels (*first revision*)
IS 6911 : 2017	Stainless steel plate, sheet and strip — Specification (*second revision*)
IS 10801 : 1984	Recommended procedure for heat treatment of welded fabrications
IS 13805 : 2004	General standard for qualification and certification of non-destructive testing personnel — Specification (*first revision*)
IS 16003 : 2012	Specification and qualification of welding procedures for metallic materials — General rules
IS 16848 : 2018/ISO 6502 : 2016	Rubber — Guide to the use of curemeters
IS 7310 (Part 1) : 2019/ISO 9606-1 : 2012	Qualification testing of welders — Fusion welding: Part 1 Steels (*first revision*)

3 TERMINOLOGY

For the purpose of this standard, following definition(s) shall apply:

3.1 Specific Gravity — It is the ratio between the mass of the blended mix of the compound with respect to equivalent mass of water. It is an index to control the adding ingredients in right proportion as per design formulation.

3.2 Rheological Study — It describes curing and processing characteristics of compounds in terms of curing time and flow characteristics. For leak sealing compound, curing rate is kept in the range of 5 minutes to 30 minutes depending upon the nature of application.

3.2.1 *Curing Process* — In some cases, like online sealing on a cold line/ambient temperature line, external heat application using steam hose/lance may be required for curing the thermosetting compound. The need for such applications shall be identified well in advance and the heat application and time for which it is applied shall be a part of the sealing procedure.

3.3 Auto-Ignition — The auto-ignition temperature or kindling point of a substance is the lowest temperature at which it spontaneously ignites in normal atmosphere without an external source of ignition, such as a flame or spark.

3.4 Thermal Gravimetric Analysis (TGA) — Thermal gravimetric analysis (TGA) is a method of thermal analysis in which changes in physical and chemical properties of compounds are measured as a function of increasing temperature with constant heating rate or as a function of time with constant temperature. This is tested to ascertain the thermal stability of the compound at the specified temperature.

3.5 Clamp — A clamp is a fastening device used to hold or secure objects tightly together to prevent movement or separation through the application of inward pressure.

3.6 Adaptor — It is a restrictor through which compounds are injected inside the clamp.

4 REQUIREMENTS FOR LEAK SEALING JOBS — CLAMP, ADAPTOR AND COMPOUNDS

4.1 Clamps

4.1.1 *General*

4.1.1.1 Online sealing clamps can be non-structural (designed to contain leaks) or structural (designed to reinforce and hold together a damaged component).

4.1.1.2 Mechanical clamps can have a variety of shapes (for example, cylindrical, rectangular, with either flat or formed heads), often following the contour of the pipe or component being repaired. Mechanical clamps can also be used to enclose components such as flanges and valves or fittings, branches, nozzles, or vents and drains. Mechanical clamps are custom made of 2 more halves of shell/plate, bolts/studs and nuts. The annular space between the mechanical clamp and the repaired component is filled, or lined with epoxy, sealant, fiber, refractory materials, or other compounds.

4.1.2 *Material Selection*

4.1.2.1 Clamp materials must be compatible with the fluid, pressure, and temperature, with due consideration for the stagnant condition created by a leak of fluid into the clamp. The mechanical clamp sealing element and its lubricant may prevent its use in high-temperature service. Generally, the material of construction of the clamp should be similar to the clamped component. Clamps made of different materials shall be acceptable if they are compatible with the process and existing components. The clamp design and construction, including material selection, shall be done considering the deterioration mode that led to the need for the repair. The clamp shall be suitable for resisting this deterioration mode for the life of the repair.

4.1.2.2 Material selection for the clamp shall be done based on the compatibility with service fluid (all possible damage mechanisms shall be considered).

4.1.2.3 Material selection shall be done based on maximum temperature and pressure that the clamp might be exposed to while in service.

a) Plates used in the fabrication of clamps should be made up of carbon steel conforming to grades mentioned in the table below for temperature not exceeding 454 ˚C:

Sl No.	*Grade*	*Chemical and Mechanical Requirements*
i)	Grade 70	*see* Table 3 and Table 4
ii)	Grade 60	*see* Table 3 and Table 4
iii)	E 250 A	*see* IS 2062
iv)	E 250 B	*see* IS 2062
v)	E 250 C	*see* IS 2062

b) Pipes used in the fabrication of clamps should be made up of carbon steel conforming to grades mentioned in the table below for temperature not exceeding 454 ˚C:

Sl No.	*Grade*	*Chemical and Mechanical Requirements*
i)	Grade B	*see* Table 5 and Table 6
ii)	Grade C	*see* Table 5 and Table 6

c) Plates used in the fabrication of clamps should be made up of alloy steel or stainless-steel conforming to grades mentioned in the table below for temperature up to 816 ˚C:

Sl No.	*Grade*	*Chemical and Mechanical Requirements*
i)	316	*see* IS 6911
ii)	316 L	*see* IS 6911
iii)	316 H	*see* IS 6911
iv)	304 N	*see* IS 6911
v)	304 S2	*see* IS 6911
vi)	304 H	*see* IS 6911
vii)	SA 387 11	*see* Table 7 and Table 8
viii)	SA 387 22	*see* Table 7 and Table 8
ix)	SA 387 91	*see* Table 7 and Table 8

d) Pipes used in the fabrication of clamps should be made up of alloy steel or stainless-steel conforming to grades mentioned in the table below for temperature up to 816 ˚C:

Sl No.	*Grade*	*Chemical and Mechanical Requirements*
i)	316	*see* IS 6911
ii)	316 L	*see* IS 6911
iii)	316 H	*see* IS 6911
iv)	304 N	*see* IS 6911
v)	304 S2	*see* IS 6911
vi)	304 H	*see* IS 6911
vii)	P 11	*see* Table 9 and Table 10
viii)	P 22	*see* Table 9 and Table 10
ix)	P 91	*see* Table 9 and Table 10

e) All fasteners to be used as a part of the sealing device/clamp should conform to grades mentioned in the table below:

Sl No.	*Grade*	*Fastener Type*	*Operating Temperature*	*Chemical and Mechanical Requirements*
i)	B7	Bolts	Recommended to be used for temperature not exceeding 538°C	*see* Table 11 and 13
ii	2H	Nuts	Recommended to be used for temperature not exceeding 538 °C	*see* Table 12 and 14
iii	B16	Bolts	Recommended to be used for temperature up to 816 °C	*see* Table 11 and 13
iv)	8M	Nuts	Recommended to be used for temperature up to 816 °C.	*see* Table 12 and 14

4.1.3 *Design*

4.1.3.1 Clamp should be engineered, designed and manufactured as per recognized codes and standards like IS 2825 for design calculation. Design calculation should specify the grade of plate/pipe depending upon design operating, pressure, temperature, operating fluid, etc.

4.1.3.2 In case of thinned down pipeline, retainer clamp shall be used to avoid accident and failure of pipe.

4.1.3.3 Design calculation of online sealing clamps for flange and pipes is furnished in Annex B.

4.1.4 *Fabrication*

a) The clamp manufacturer/fabricator shall be having approved welding procedures, PQR's (Procedure Qualification Record) complying with the requirements of IS 1179, IS 16003 and IS 822.

b) All welding shall be carried out by qualified welders.

c) Welding shall be carried out as per the standard welding procedures including stress relieving. Post weld heat treatment shall be done as per IS 10801.

d) Material for clamp fabrication shall be positively identified. Material test certificates (MTC's) of the material being utilized for clamp fabrication shall be available along with traceability certificates.

e) Layer of welding shall be mentioned in the clamp drawing depending on the plate thickness and to be free from ripples and shall be ground to required profiles.

f) Welding shall be done with low hydrogen electrode. Welding (including fillet welds) in carbon steel components can be done with EB44A6 electrode conforming to IS 814. In case of clamp designed from stainless steel, then welding can be done by shielded metal arc welding (SMAW) process using E19.12.2L electrode conforming to IS 5206.

g) Root pass of full penetration welds with groove joint design shall be by gas tungsten arc welding (GTAW) process.

h) All welds shall be visually inspected, free of ripples and spatter, ground to required profiles and shall be of sound workmanship. Wherever access is available, back chipping shall be done to prevent root discontinuities.

j) All welds shall be at least liquid penetrant tested, as a minimum. Radiographic testing shall be done in case of critical applications or as per end user’s requirements.

k) Hydro testing of clamp, at design pressure (or value stated by the end user), shall be carried out by the fabrication agency, if mandated by end user. The same shall be witnessed by the representative of end user or an appointed third-party inspector.

4.2 Adaptors

4.2.1 Hundred percent raw material test shall be carried out for element concentration of the alloy steel manufacturers through optical emission spectroscopy to ascertain pressure rating.

4.2.2 Type test for pressure withstanding capacity of the adapter shall be carried out every three years for each grade and type of adapter. The pressure test shall be carried out at least 1.2 times the line design pressure where the adaptor will be used.

4.3 Sealing Compounds

4.3.1 The operating temperature (of the process fluid from the leaking component) shall be at least 50 ˚C less than auto-ignition temperature of the sealing compound for safe use of compound under the specified temperature, pressure in presence of oxygen.

4.3.2 Maximum 15 % of degradation for thermo-setting compound and 30 % degradation for non-thermosetting compounds at the specified temperature is the acceptable limit.

4.3.3 Manufacturer should provide Material Safety Data Sheets (MSDS) of compounds recommended to use.

4.3.4 The properties of sealing compounds based on different types shall be as given in Table 1. The compounds shall be tested for different properties as per the standard test methods mentioned in the table below:

Property	*Test Method*
Specific gravity	IS 3400 (Part 9)
Rheology, t’c(90)	IS 16848
Auto-ignition	IS 1448 (Part 87)
Thermo gravimetric analysis (Percentage degradation)	*see* Annex C

4.3.5 Chemical compatibility with the service fluid shall be checked and to be selected based on the type of sealing compound and operating temperature as given in Table 2.

Table 1 Test Requirements for Sealing Compounds

(*Clause* 4.3.4)

Sl No.	**Compound Type**	**Specific Gravity** (± 0.5)	**Rheology** $t'_c(90)$, At 160 °C (*Max*)	**Auto-Ignition** (*Min*)	**TGA** (Percentage Degradation, *Max*)
(1)	(2)	(3)	(4)	(5)	(6)
i)	Type 1 (T)	1.7	20 min	300 °C	10 % at 250 °C
ii)	Type 2 (T)	1.7	10 min	250 °C	10 % at 120 °C
iii)	Type 3 (T)	1.7	25 min	350 °C	15 % at 300 °C
iv)	Type 4 (T)	1.7	28 min	400 °C	15 % at 350 °C
v)	Type 5 (NT)	1.7	N. A	500 °C	25 % at 450 °C
vi)	Type 6 (T)	1.7	20 min	270 °C	10 % at 220 °C
vii)	Type 7 (T)	1.7	N. A	900 °C	20 % at 850 °C
viii)	Type 8 (NT)	1.7	N. A	210 ˚C	10 % at 100 °C
ix)	Type 9 (T)	1.7	25 min	350 °C	10 % at 250 °C

Table 1 (*Concluded*)

Sl No. (1)	**Compound Type** (2)	**Specific Gravity** (± 0.5) (3)	**Rheology** t'_c(90), At 160 °C, (*Max*) (4)	**Auto-Ignition** (*Min*) (5)	**TGA** (Percentage Degradation, *Max*) (6)
x)	Type 10 (T)	1.7	10 min	400 °C	15 % at 350 °C
xi)	Type 11 (NT)	1.7	N. A	290 °C	15 % at 240 °C
xii)	Type 12 (NT)	1.7	N. A	290 °C	25 % at 240 °C
xiii)	Type 13 (T)	1.7	N. A	150 °C	5 % at 100 °C
xiv)	Type 14 (NT)	1.7	N. A	150 °C	5 % at 100 °C
xv)	Type 15 (T)	1.7	15 min	500 °C	20 % at 450 °C
xvi)	Type 16 (T)	1.7	25 min	350 °C	10 % at 300 °C
xvii)	Type 17 (NT)	1.7	N. A	550 °C	25 % at 500 °C
xviii)	Type 18 (T)	1.7	15 min	210 °C	20 % at 400 °C
xix)	Type 19 (T)	1.7	30 min	350 °C	20 % at 400 °C
xx)	Type 20 (T)	1.7	25 min	500 °C	25 % at 550 °C

Table 2 General Selection Guidelines of Sealing Compounds Based on Operating Temperature
(*Clause* 4.3.5)

Sl No. (1)	**Compound** (2)	**Operating Temperature** (3)	**Suitable Media** (4)
i)	Type 1 (T)	100 °C to 250 °C	Steam, boiler feed water and some chemicals like acetylene, ammonia, caustic (NaOH), methanol, isobutane, mono-ethylene glycol (MEG), nitrogen, poly-ethylene glycol (PEG), potassium carbonate, caustic soda (10 % to 60 % concentration), high-density poly ethylene (HDPE), triethyl aluminum, CO, citric acid, di-sodium, phosphate, quench water, etc.
ii)	Type 2 (T)	80 °C to 200 °C	Feed water, Ammonia Gas, PEG, MEG, crude glycol, NaOH, demineralised water, isobutanol, Nitrogen, potassium carbonate, caustic soda (10 % to 60 % concentration), triethyl aluminum, CO, citric acid, quench water, acetylene, etc.
iii)	Type 3 (T)	160 °C to 300 °C	Hydrocarbon, sea water, higher aniline point mineral oil above 100 Bar, PEG, MEG, crude glycol, low sulphur heavy stock (LSHS), CO_2, isobutanol, nitrogen, slop oil, spent caustic, mixed oil, pentane, titanium peroxide, oligomer, acetylene, CO, vaseline grease, triethylaluminium, $TiCl_4$, lean gas, C4 mix,

Table 2 (*Continued*)

Sl No. (1)	**Compound** (2)	**Operating Temperature** (3)	**Suitable Media** (4)
			ammonia, lube oil, methanol, H_2, propane, ethylene, etc.
iv)	Type 4 (T)	160 °C to 350 °C	Hydrocarbon, higher aniline point mineral oil upto 100 bar, PEG, MEG, crude glycol, oligomer, ammonia, isobutanol, N_2, acetylene, ammonia gas, CO, pentane, methanol, etc.
v)	Type 5 (NT)	250 °C to 450 °C	Super-heated steam.
vi)	Type 6 (T)	Ambient to 220 °C	Naphtha, kerosene, diesel, petrol, CO, flu gas, hydrocarbon derivatives, ethylene, propylene, methane, acetylene, gasoline, methanol, MEG, PEG, hydrazine hydrate, nitrogen, chloroform, CO, lean gas, potassium carbonate, ethane, CO_2, chlorine, phosphoric acid, etc.
vii)	Type 7 (T)	450 °C to 850 °C	Super-heated steam, air, hydrocarbon derivatives, etc.
viii)	Type 8 (NT)	Ambient to 160 °C	LPG, C4 Mix, etc.
ix)	Type 9 (T)	160 °C to 300 °C	Inorganic acids, steam, high density polyethylene (HDPE), low density polyethylene (LDPE), etc.
x)	Type 10 (T)	350 °C, *Max*	Thermic fluid like hytherm 500, oxygen, chlorine, benzene, etc.
xi)	Type 11 (NT)	- 100 °C to 240 °C	Hydrocarbon derivatives, ethane, propane, ethylene, propylene, methane, morpholine, benzene, dimethyl disulphide (DMDS), $TiCl_4$, methylene acetylene, H_2, etc.
xii)	Type 12 (NT)	- 85 °C to 240 °C	Hydrocarbon derivatives, ethane, propane, ethylene, propylene, methane, morpholine, benzene, dimethyl disulphide (DMDS), $TiCl_4$, methylene acetylene, H_2, etc.
xiii)	Type 13 (T)	Ambient to 160 °C	Di ethanol amine/mixed amine, amino acid, tri sodium phosphate, methyl ethyl ketoxime (MEKOR), DMF, off-gas, atmer163, etc.
xiv)	Type 14 (NT)	- 40 °C to 160 °C	Anhydrous and concentrated HCl media, halogenated inorganic acid, glycols, alcohols, etc.
xv)	Type 15 (T)	160 °C to 400 °C	Transformer oil leakage, citric acid, NaOH, N_2, Ammonia Gas, methanol, MEG, isobutanol, crude glycol, PEG, phosphoric acid, etc.
xvi)	Type 16 (T)	160 °C to 300 °C	Kerosene, diesel, petrol, triethyl aluminum, titanium peroxide, ethane, propane, ethylene, isobutanol, MEG, Methane, H_2 gas, poly-PEG, gasoline, ammonia, CO, vaseline grease, oligomer, n-pentane, C4 mix, ammonia, methanol, nitrogen, lube oil, crude glycol, mixed oil, high speed diesel (HSD), pentane,

Table 2 (*Concluded*)

Sl No. (1)	Compound (2)	Operating Temperature (3)	Suitable Media (4)
			low sulphur heavy stock (LSHS), hexane-1, spent caustic, slop oil, CO_2, lean gas, etc.
xvii)	Type 17 (NT)	500 °C, *Max*	Water, steam, air, etc (specially for valve gland leakage).
xviii)	Type 18 (T)	350 °C, *Max*	Glacial acetic acid and carboxylic acids.
xix)	Type 19 (T)	160 °C to 300 °C	Re injection for Type 16, Type 3, Type 4, Type 8 etc.
xx)	Type 20 (T)	300 °C to 450 °C	Re injection for Type 5, Type 16, etc.

NOTES

1 Thermosetting compound (T) — Thermosetting compound is defined where a soft rubber compound is cured by induced heat and pressure in presence curative chemicals that become rigid and non-deformable after irreversibly hardening.

2 Non-Thermosetting compound (NT) — Polymers in the compound mutually attract each other under heat and pressure due to presence of relatively week secondary forces in the basic polymer and generate a unit mass.

5 HAZARDS IDENTIFICATION AND RISK ASSESSMENT, CONTROL MEASURES FOR ONLINE LEAK SEALING

An on-line leak sealing job should be properly planned. Before it is decided to do on-line leak sealing, all concerned disciplines namely operation, maintenance, engineering, and safety should jointly assess various risks involved. Accordingly, detailed risk assessment sheet needs to be prepared, various conditions checked, and necessary corrective measurements needs to be taken for each type of risk involved for a safe and successful online leak sealing job.

Detailed procedure may be outlined for carrying out online leak sealing which may include following:

a) Basic information and pre-assessment of online leak sealing work — This may include equipment/piping identification details, process details and personnel involved, etc.

b) Online Leak sealing Procedure — This shall include the detailed procedure for execution of job including the risk assessment and control measures, sealing compound, clamp details, competency of the job executing personnel and approval matrix, etc.

c) Execution of online leak sealing job — This part shall cover right from permit to work, emergency procedure and monitoring of work execution, etc till successful execution of the job including re-injection process, if required.

d) Normalization of online leak sealing jobs — Being a temporary repair, online sealed leaks need to be monitored on a continual basis and restored normalcy by removing the sealant/clamp at the earliest during the nearest available shutdown opportunity.

6 TOOLS AND TACKLES

Following tools and tackles are required, in general, for installation of online sealing clamp and injection of sealant:

a) Set of spanners for installation of fasteners and adapters;
b) Screw drivers, crow bars and other general hand tools;
c) Pneumatic wrenches with sockets,
d) Pneumatic drill machine or power operated drill machine;
e) Drill bits;
f) Hand taps;
g) Hand operated hydraulic pump with hose, pressure gauge and other accessories;
h) Injection device;
j) Spare adapters;
k) Grub screws for sealing injection points/ overflow points;
m) Pneumatic jackhammer; and
n) Peening wire.

It is to be ensured that:

a) All tools and tackles are in good working condition, of standard quality and free from defects.

b) No fabricated tools or makeshift tools shall be used.

c) All power tools shall be having adequate protection against electrocution hazard.

d) Adequate certification of power tools when intended to be used in hazardous environments.

e) All the pressure gauges shall be having a valid calibration certificate.

f) All the hydraulic hoses and connections shall be free from defects.

g) Proper Personal Protective Equipment (PPE's) shall be provided to the working crew, based on the hazards (for example, leather gloves for working on high temperature piping/equipment etc.)

7 RE-WORK, RE-INJECTION INTO ONLINE SEALING CLAMP

7.1 Re-injection in an existing clamp is riskier than the original online sealing activity because of following reasons:

a) The clamp, internals and the fasteners may have got deteriorated because of exposure to service media, atmospheric conditions and/or due to being under stress.

b) The original component might have deteriorated under the clamp and may have lost its structural strength.

c) Higher pressure may be required to inject fresh compound against the already present cured compound bulk in the clamp. This may lead to excessive stresses on the clamp and the fasteners.

d) No means of evaluating the original component are available and this becomes a big variable in the risk equation.

7.2 Any rework/re-injection shall be properly planned with following minimum requirements:

a) Re-injection shall not be allowed in corrosive services, or in services where flashing/expansion/rapid vaporization may take place. It should also not be allowed in toxic and flammable services.

b) Any decision on re-injection shall be consciously taken and approved by operations, maintenance and health, safety and environment (HSE) department jointly.

c) Feasibility of re-injection shall be ascertained in consultation with the online sealing service provider.

d) The reinjection job must follow at least the same approval path as the original request and/or the approval authorities shall be escalated one level up considering the additional risk.

e) A task specific risk assessment covering all the emergency scenarios shall be prepared for field execution.

f) Acceptance criteria and the conditions in which the job shall be terminated (with no further attempts of reworking) shall be mutually agreed upon, by the client and the service provider. Re-injection shall be done in accordance with approved procedure.

8 COMPETENCY REQUIREMENTS OF WORKING PERSONNEL

Following shall be minimum qualifications of the personnel involved in online sealing process:

a) Engineer designing the clamp shall be a graduate mechanical engineer with 4 years to 5 years of experience in the field of designing pressure boundaries. He shall be well versed with latest versions of applicable design codes and fabrication practices. He shall be capable of performing/validating design calculations and shall be conversant with the use of design software.

b) The designer/draftsmen should be capable of producing detailed drawings of the clamps with all the required details, bill of materials (BOM) and operating conditions for which the clamp is designed.

c) All welding should be done by individuals qualified as per IS 7310.

d) All NDT shall be performed by individuals certified to level II or level III as per IS 13805. All NDT records shall be shared with the client as a part of the design package.

e) Any online sealing job shall be executed by competent, trained personnel; qualified in performing such tasks, following the approved procedure, and validated by the service provider.

f) It is preferable that the execution crew be having ample amount of hands-on experience (4 years to 5 years) but the final authority on selection of crew shall be with the service provider.

g) The client engineer shall be well versed with all the applicable codes and best practices and shall be capable of reviewing and validating the drawing as well as design calculations.

h) The client engineer shall be experienced in coordinating online sealing jobs, and shall be able to identify the prerequisites and line up necessary resources.

ANNEX A

(*Clause* 4.1.2.3)

CHEMICAL AND MECHANICAL REQUIREMENTS OF PLATES, PIPES AND FASTENERS USED IN FABRICATION OF CLAMPS

A-1 The chemical and mechanical requirements of plates and pipes for operating temperature not exceeding 454 °C is given in Table 3 to Table 6.

Table 3 Chemical Requirements of Plates for Operating Temperature not Exceeding 454 °C

(*Clause* 4.1.2.3)

Sl No.	Elements	Composition, % by weight	
		Grade 60	Grade 70
(1)	(2)	(3)	(4)
i)	Carbon, *Max*[1),2)]:		
	t ≤ 12.5 mm	0.21	0.27
	12.5 < t ≤ 50 mm	0.23	0.28
	50 < t ≤ 100 mm	0.25	0.30
	100 < t ≤ 200 mm	0.27	0.31
	t > 200 mm	0.27	0.31
ii)	Manganese[2)]:		
	t ≤ 12.5		
	Heat analysis	0.60 to 0.90[3)]	0.85 to 1.20
	Product analysis	0.55 to 0.98[3)]	0.79 to 1.30
	t > 12.5		
	Heat analysis	0.85 to 1.20	0.85 to 1.20
	Product analysis	0.79 to 1.30	0.79 to 1.30
iii)	Phosphorus, *Max*[1)]	0.025	0.025
iv)	Sulphur, *Max*[2)]	0.025	0.025
v)	Silicon		
	Heat analysis	0.15 to 0.40	0.15 to 0.40
	Product analysis	0.13 to 0.45	0.13 to 0.45

[1)] Applies to both heat and product analysis.

[2)] For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50 percent by heat analysis and 1.60 percent by product analysis.

[3)] Grade 60 plates, 12.5 mm and under in thickness may have 0.85 percent to 1.20 percent manganese on heat analysis, and 0.79 percent to 1.30 percent manganese on product analysis.

NOTE — ‘t’ is the thickness of plate.

Table 4 Mechanical Requirements of Plates for Operating Temperature not exceeding 454 °C

(*Clause* 4.1.2.3)

Sl No. (1)	Requirement (2)	Grade 60 (3)	Grade 70 (4)
i)	Tensile strength, MPa	415 to 550	485 to 620
ii)	Yield strength, MPa, *Min*	220	260
iii)	Elongation in 200 mm, percent, *Min*	21	17
iv)	Elongation in 50 mm, percent, *Min*	25	21

Table 5 Chemical Requirements of Pipes for Operating Temperature not Exceeding 454 °C
(*Clause* 4.1.2.3)

Sl No.	Elements	Composition, % by weight	
		Grade B	Grade C
(1)	(2)	(3)	(4)
i)	Carbon, *Max*	0.30[1]	0.35[2]
ii)	Manganese	0.29 to 1.06	0.29 to 1.06
iii)	Phosphorus, *Min*	0.035	0.035
iv)	Sulphur, *Min*	0.035	0.035
v)	Silicon, *Min*	0.10	0.10
vi)	Chromium, *Min*[2]	0.40	0.40
vii)	Copper, *Min*[2]	0.40	0.40
viii)	Molybdenum, *Min*[2]	0.15	0.15
ix)	Nickel, *Min*[2]	0.40	0.40
x)	Vanadium, *Min*[2]	0.08	0.08

---

[1] Unless otherwise specified by the purchaser, for each reduction of 0.01 percent below the specified carbon maximum, an increase of 0.06 percent manganese above the specified maximum will be permitted up to a maximum of 1.65 percent

[2] These five elements combined shall not exceed 1 percent.

Table 6 Mechanical Requirements of Pipes for Operating Temperature not Exceeding 454 °C
(*Clause* 4.1.2.3)

Sl No.	Requirements	Grade B		Grade C	
(1)	(2)	(3)		(4)	
i)	Tensile strength, MPa, *Min*	415		485	
ii)	Yield strength, MPa, *Min*	240		275	
		Longitudinal	Transverse	Longitudinal	Transverse
iii)	Elongation in 50 mm, percent, *Min* Basic minimum elongation transverse strip tests, and for all small sizes tested in full section	30	16.5	30	16.5
iv)	When standard round 50 mm gauge length test specimen is used	22	12	20	12
v)	For longitudinal strip tests	[1]	-	[1]	-
vi)	For transverse strip tests, a deduction for each 0.8 mm decrease in wall thickness below 7.9 mm from the basic minimum elongation of the following percentage shall be made	-	1.00	-	1.00

---

[1] The minimum elongation in 50 mm shall be determined by the following equation:

$$e = 1940A^{0.2}/U^{0.9} \text{ for SI units,}$$

where

e = minimum elongation in 50 mm, in percentage, rounded to the nearest 0.5 percent

A = cross-sectional area of the tension test specimen mm^2, based upon specified outside diameter or nominal specimen width and specified wall thickness, rounded to the nearest 1 mm^2. (If the area thus calculated is equal to or greater than 500 mm, then the value 500 mm^2 shall be used)

U = specified tensile strength, MPa.

A-2 The chemical and mechanical requirements of plates and pipes for operating temperature beyond 816 °C is given in Table 7 to Table 10.

Table 7 Chemical Requirements of Plates for Operating Temperature up to 816 °C.
(*Clause* 4.1.2.3)

Sl No.	**Element**	**Composition, percent by weight**			
		Grade 11	**Grade 22**	**Grade 91 Type 1**	**Grade 91 Type 2**
(1)	(2)	(3)	(4)	(5)	(6)
i)	Carbon:				
	Heat analysis	0.05 to 0.17	0.05 to 0.15[1)]	0.08 to 0.12	0.08 to 0.12
	Product analysis	0.04 to 0.17	0.04 to 0.15[1)]	0.06 to 0.15	0.06 to 0.15
ii)	Manganese:				
	Heat analysis	0.40 to 0.65	0.30 to 0.60	0.30 to 0.60	0.30 to 0.50
	Product analysis	0.35 to 0.73	0.25 to 0.66	0.25 to 0.66	0.30 to 0.50
iii)	Phosphorus, *Max*:				
	Heat analysis	0.025	0.025	0.020	0.020
	Product analysis	0.025	0.025	0.025	0.020
iv)	Sulphur, *Max*:				
	Heat analysis	0.025	0.025	0.010	0.005
	Product analysis	0.025	0.025	0.012	0.005
v)	Silicon:				
	Heat analysis	0.50 to 0.80	0.50 *Max*	0.20 to 0.50	0.20 to 0.40
	Product analysis	0.44–0.86	0.50 *Max*	0.18 to 0.56	0.20 to 0.40
vi)	Chromium:				
	Heat analysis	1.00 to 1.50	2.00 to 2.50	8.00 to 9.50	8.0 to 9.50
	Product analysis	0.94 to 1.56	1.88 to 2.62	7.90 to 9.60	8.0–9.50
vii)	Molybdenum:				
	Heat analysis	0.45 to 0.65	0.90 to 1.10	0.85 to 1.05	0.85 to 1.05
	Product analysis	0.40 to 0.70	0.85 to 1.15	0.80 to 1.10	0.80 to 1.05

Table 7 (*Concluded*)

Sl No.	Element	Composition, percent by weight			
		Grade 11	**Grade 22**	**Grade 91 Type 1**	**Grade 91 Type 2**
(1)	(2)	(3)	(4)	(5)	(6)
viii)	Nickel, *Max*:				
	Heat analysis	-	-	0.40	0.20
	Product analysis	-	-	0.43	0.20
ix)	Vanadium:				
	Heat analysis	-	-	0.18 to 0.25	0.18 to 0.25
	Product analysis	-	-	0.16 to 0.27	0.16 to 0.27
x)	Columbium (niobium):	-			
	Heat analysis			0.06 to 0.10	0.06 to 0.10
	Product analysis			0.05 to 0.11	0.05 to 0.11
xi)	Boron, *Max*[2)]				0.001
xii)	Nitrogen:				
	Heat analysis	-	-	0.030 to 0.070	0.035 to 0.070
	Product analysis	-	-	0.025 to 0.080	0.035 to 0.070
xiii)	Nitrogen/aluminum	-	-	-	≥ 4.0
xiv)	Aluminum, *Max*[2)]	-	-	0.02	0.020
xv)	Titanium, *Max*[2)]	-	-	0.01	0.01
xvi)	Zirconium, *Max*[2)]	-	-	0.01	0.01
xvii)	Tungsten, *Max*[2)]	-	-	-	0.05
xviii)	Copper, *Max*[2)]	-	-	-	0.10
xix)	Antimony, *Max*[2)]	-	-	-	0.003
xx)	Arsenic, *Max*[2)]	-	-	-	0.010
xxi)	Tin, *Max*[2)]	-	-	-	0.010

[1)] Carbon content for plates over 125 mm in thickness is 0.17 *Max* on product analysis.

[2)] Applies to both heat and product analysis.

Table 8 Mechanical Requirements for of Plates for Operating Temperature up to 816 °C.

(*Clause* 4.1.2.3)

Sl No.	**Requirement**	**Grade 11**		**Grade 22**		**Grade 91**
		Class 1	Class 2	Class 1	Class 2	
(1)	(2)	(3)		(4)		(5)
i)	Tensile strength, (MPa)	415 to 585	515 to 690	415 to 585	515 to 690	585 to 760
ii)	Yield strength, *Min,* (MPa)	240	310	205	310	415
iii)	Elongation in 200 mm, *Min*, %	19	18	–	–	–
iv)	Elongation in 50 mm, *Min*, %	22	22	18	18	18
v)	Reduction of area, *Min*, %	–	–	45[1] 45[1]	40[2] 40[2]	–

---

[1] Measured on round test specimens.

[2] Measured on flat specimen

Note — Class 2 plates are not applicable to annealed material.

Table 9 Chemical Requirement of Pipes for Operating Temperature up to 816 ˚C.

(*Clause* 4.1.2.3)

Sl No.	**Grade**	**Element Composition, percent by weight**							
		Carbon	Manganese	Phosphorus, *Max*	Sulphur	Silicon	Chromium	Molybdenum	Others
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	P11	0.05 to 0.15	0.30 to 0.60	0.025	0.025	0.50 to 1.00	1.00 to 1.50	0.44 to 0.65	….
ii)	P22	0.05 to 0.15	0.30 to 0.60	0.025	0.025	0.50 Max	1.90 to 2.60	0.87 to 1.13	….

Table 9 (*Concluded*)

Sl No.	Grade	Element Composition, percent by weight							
		Carbon	Manganese	Phosphorus, *Max*	Sulphur	Silicon	Chromium	Molybdenum	Others
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
iii)	P91 Type 1	0.08 to 0.12	0.30 to 0.60	0.020	0.010	0.20 to 0.50	8.00 to 9.50	0.85 to 1.05	V 0.18 to 0.25 N 0.030 to 0.070 Ni 0.40 *Max* Al 0.02 *Max* Cb 0.06 to 0.10 Ti 0.01 *Max* Zr 0.01 *Max*
iv)	P91 Type 2:								
	Heat	0.08 to 0.12	0.30 to 0.50[1]	0.020[1]	0.005[1]	0.20 to 0.40[1]	8.00 to 9.50[1]	0.85 to 1.05	V Heat 0.18 to 0.25 Product 0.16 to 0.27 Ni 0.20 *Max*[1] Al 0.020 *Max*[1] N 0.035 to 0.070 N/Al ratio ≥ 4.0 Cb Heat 0.06 to 0.10 Product 0.05 to 0.11 Ti 0.01 *Max*[1] Zr 0.01 *Max*[1] Sn 0.010 *Max*[1] Sb 0.003 *Max*[1] As 0.010 *Max*[1] B 0.001 *Max*[1] W 0.05 *Max*[1] Cu 0.10 *Max*[1]
	Product	0.07 to 0.13						0.80 to 1.05	

---

[1] Applies to both heat and product analyses.

Table 10 Mechanical Requirements of Pipes for Operating Temperature up to 816 °C.

(*Clause* 4.1.2.3)

Sl No. (1)	**Requirement** (2)	**Grade P11, P22** (3)	**Grade P91 Type 1 and Type 2** (4)
i)	Tensile strength, MPa, *Min*	415	585
ii)	Yield strength, MPa, *Min*	205	440

A-3 The chemical and mechanical requirements of bolts and nuts as part of the sealing device/clamp is given in Table 11 to Table 14.

Table 11 Chemical Requirement of Bolts

(*Clause* 4.1.2.3)

Sl No.	**Grade**	**Elements Composition, percent by weight**							
		Carbon	Manganese	Phosphorus	Sulphur	Silicon	Chromium	Nickel	Molybdenum
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	B7,	0.38 to 0.48	0.75 to 1.00	0.035	0.040	0.15 to 0.35	0.80 to 1.10	-	0.15 to 0.25
	Product analysis variation[1]	0.02	0.04	0.005	0.005	0.02	0.05	-	0.02
ii)	B16,	0.36 to 0.47	0.45 to 0.70	0.035	0.040	0.15 to 0.35	0.80 to 1.15	-	0.50 to 0.65
	Product analysis variation[1]	0.02	0.03	0.005	0.005	0.02	0.05	-	0.03

---

[1] Product Analysis—Individual determinations sometimes vary from the specified limits as shown in the table. The several determinations of any individual element in a heat may not vary both above and below the specified range. Product variation limits are over for maximums, over or under for ranges, and under for minimums, unless otherwise indicated.

Table 12 Chemical Requirement of Nuts
(*Clause* 4.1.2.3)

Sl No.	**Grade**	**Element Composition, % by weight**							
		Carbon	Manganese	Phosphorus	Sulphur[1]	Silicon	Chromium	Nickel	Molybdenum
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	2H	0.40 *Min*	1.00	0.040	0.050	0.40	-	-	-
ii)	8M	0.08	2.00	0.045	0.030	1.00	16.0 to 18.0	10.0 to 14.0	2.00 to 3.00

---

[1] Because of the degree to which sulphur segregates, products analysis for sulphur over 0.060 % max is not technologically appropriate.

Table 13 Mechanical Requirements of Bolts
(*Clause* 4.1.2.3)

Sl No. (1)	**Grade** (2)	**Diameter, mm** (3)	**Minimum Tempering Temperature,℃** (4)	**Tensile Strength, *Min*, MPa** (5)	**Yield Strength, *Min*, 0.2 % offset, MPa** (6)	**Elongation in 4D *Min*, %** (7)	**Reduction of Area, *Min*, %** (8)	**Hardness, *Max*** (9)
i)	B7	M64 and under	593	860	720	16	50	321 HBW or 35HRC
		over M64 to M100	593	795	655	16	50	321 HBW or 35 HRC
		over M100 to M180	593	690	515	16	50	321 HBW or 35 HRC
ii)	B16	M64 and under	650	860	725	18	50	321 HBW or 35 HRC
		over M64 to M100	650	760	655	17	45	321 HBW or 35 HRC
		over M100 to M200	650	690	585	16	45	321 HBW or 35 HRC

Table 14 Mechanical Requirements of Nuts
(*Clause* 4.1.2.3)

Sl No.	**Grade and Type**	**Brinell Hardness**	**Rockwall Nuts**	
			C Scale	**B Scale**
(1)	(2)	(3)	(4)	(5)
i)	2H, up to M36	248 to 327	24 to 35	–
ii)	2H, over M36	212 to 327	35 *Max*	95 *Min*
iii)	8M	126 to 300	32 *Max*	60 *Min*

ANNEX B

(*Clause* 4.1.3.3)

DESIGN CALCULTION OF ONLINE SEALING CLAMPS

B-1 MINIMUM REQUIREMENTS FOR DESIGN OF AN ONLINE SEALING CLAMP

Following are the minimum requirements for design of an online sealing clamp:

a) Earlier proven designs on similar applications shall be considered.

b) The clamp shall be sized/designed to cover the leaking/deteriorated area.

c) The clamp shall be designed to be filled with compound completely without any annular space for accumulation of operating fluid.

d) Design calculations for the clamp shall be made based on design temperature and pressure of the leaky component.

e) All the design calculations shall be validated by the end user before the actual installation.

f) The drawing of the clamp shall be an engineering drawing and shall indicate all the details of the weld joints and size of the weld joints.

g) The drawing shall have the material details for all the components to be used in the fabrication of the clamps. The material of the clamp shall be same as that of the piping metallurgy/specifications. Superior metallurgy may be permitted in consultation with the corrosion engineer/end user.

h) Metallurgy and welding electrode details shall also be mentioned in the drawing.

j) The drawing shall include the non-destructive testing to be done on the components of the clamp and weld joints.

k) The drawing shall indicate the number of injection points of the compound.

m) The drawing shall indicate the details of the compound to be injected in the clamp.

n) The drawing shall indicate the approximate weight of the clamp.

p) Fasteners, injection valves (or adaptors) etc, shall be compatible with the service fluid and the clamp metallurgy.

q) The fasteners selection shall be based on the load requirements (code calculations) and temperature to which they may be exposed.

r) Additional supporting for the clamp, if required in field, shall be decided as a part of the design of the clamp.

B-2 DESIGN OF ONLINE LEAK SEALING CLAMP FOR THE FLANGE

B-2.1 Design quality of the flange clamp is the key to determine if the online leak sealing operation is successful. A good seal clamp should have sufficient strength and stiffness to withstand the pressure of working media and the injecting pressure of injecting sealants. Meantime, it should also have excellent seal properties to prevent the injecting sealant extravagantly and provide enough seal pressure. Among them, the strength and stiffness requirements are easier to be ensured, so how to build a good seal chamber becomes an important and difficult point of the injecting online leak sealing technology. The standard flange clamp is shown in Fig. 1.

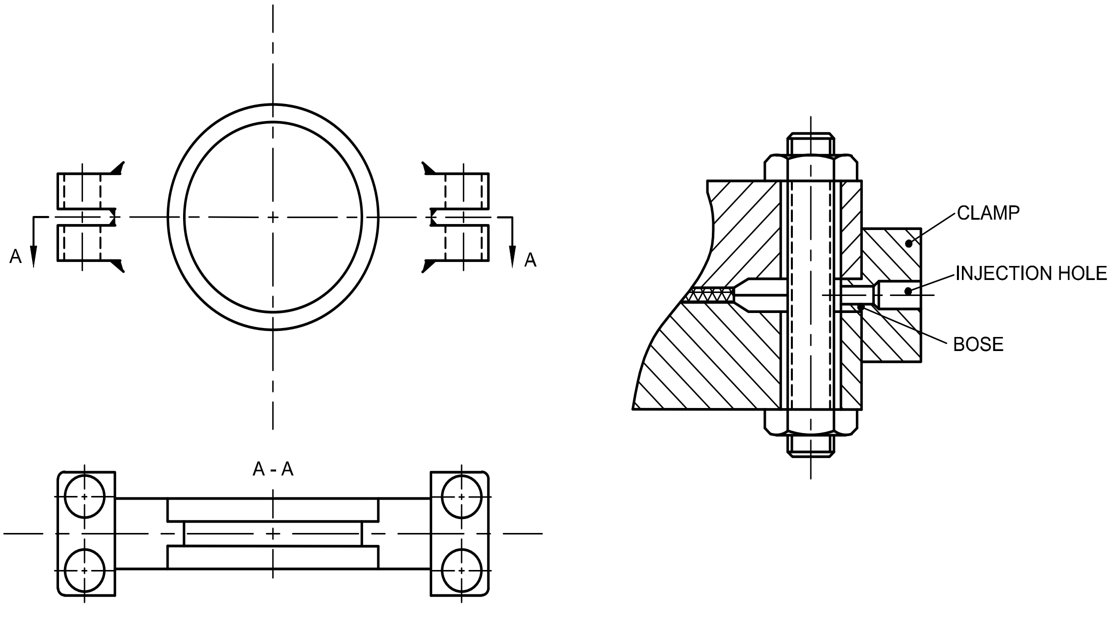

FIG.1 CONVEXITY FLANGE CLAMP

B-2.2 The seal structure of the embedded flange clamp (Fig. 2) is that two edges of the leak flanges are made a certain deformation by means of the pneumatic tool, so that the two lateral surfaces of the inner boss can contacted with the two seal faces, in order to achieve the seal effect.

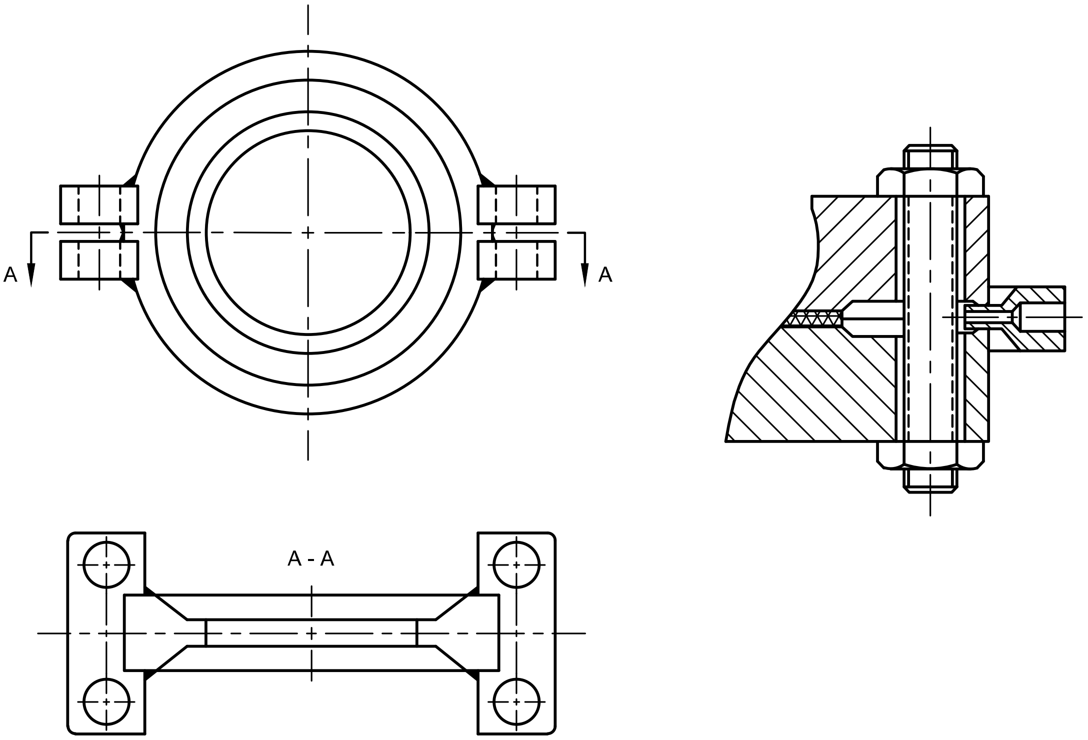

FIG. 2 THE SEAL STRUCTURE OF THE EMBEDDED FLANGE CLAMP

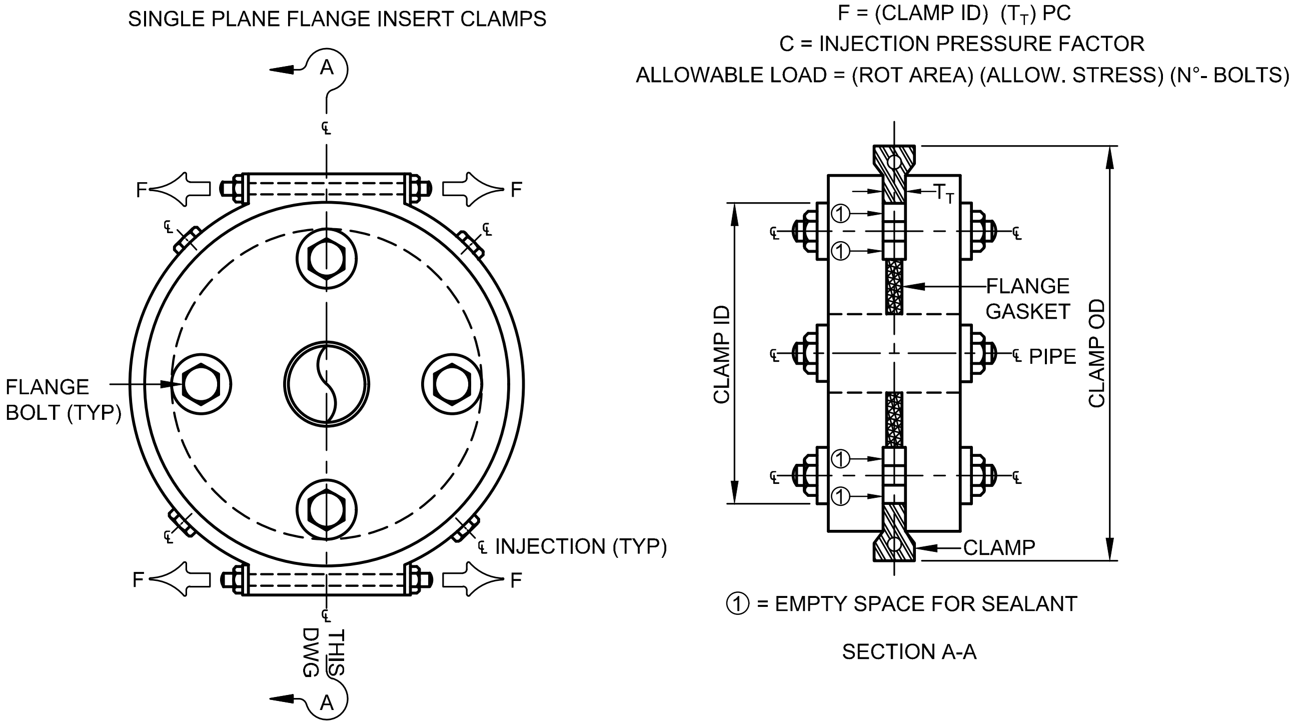
SINGLE PLANE FLANGE INSERT CLAMPS
A
F
F
F
F
FLANGE BOLT (TYP)
℄ INJECTION (TYP)
THIS DWG
A
F = (CLAMP ID) (TT) PC
C = INJECTION PRESSURE FACTOR
ALLOWABLE LOAD = (ROT AREA) (ALLOW. STRESS) (N°- BOLTS)
TT
FLANGE GASKET
℄ PIPE
CLAMP ID
CLAMP OD
CLAMP
① = EMPTY SPACE FOR SEALANT
SECTION A-A

FIG. 3 SINGLE PLANE FLANGE INSERT CLAMPS

B-2.3 Flange Insert Clamps (Insert Ring or Tongue Clamps)

When leaks occur between two flanges, the single plane inset clamp is very common and cost-effective. There are simplistic devices that consist of two plates machined to fit between the two flanges. This configuration is shown in Fig. 3.

The two ring plates have holes tapped into the sides as shown. The sealant is injected at a minimum of 1.1 times the design pressure of operating fluid. Note that in any clamp, the bolts and not the sealant, hold the clamp together. The sealant acts to seal off the leak, acting much like a gasket. Typically, the type of sealant will vary with the type of process fluid being handled and the temperatures being generated in the process. This is very important because one does not want a sealant that will chemically react with the process fluid or become unstable at the process fluid temperature.

B-2.3.1 *Calculation of number of bolts*

Fig. 3 shows the two bolts that hold the assembly together. The force acting on the bolts is as follows:

$$F = (Clamp\ ID)T_T P C_{\mathrm{inj}}$$

where

F = force acting on the bolts, in N;
ID = internal diameter of clamp, in mm;
Cinj = compound injection factor (1.1 to 1.5);
P = design pressure, in N/mm^2; and
T_T = the thickness of the space between the flanges, in mm.

The clamp internal diameter is summation of bolt circle diameter and flange bolt hole diameter. The allowable load on each bolts is as follows:

$$F_{allow} = A_B \sigma_B$$

where

A_B = the root area of each bolt, mm^2 ;
σ_B = allowable stress for the bolt material; in N/mm^2 and
n = number of bolts in clamp.

Thus, the number of bolts required, *n*, is:

$$n = F/F_{allow}$$

B-2.3.2 *Calculation of clamp thickness*

$$\text{Actual clamp thickness} = \frac{Clamp\ OD - Clamp\ ID}{2}$$

where

OD = external diameter of clamp, in mm;

Actual claim thickness shell be greater than the required clamp thickness calculated by the formula given below:

$$t = \frac{PCinjR_i}{(E)(\sigma_a)\text{-}0.6PCinj}$$

where

R_i = clamp internal radius;

E = joint efficiency; and

σ_a = allowable stress of clamp material.

The joint efficiency is usually taken to be 1.0, as this clamp is made of forged material or solid plate. For welded joints, E is usually 0.7.

B-3 DESIGN OF ONLINE LEAK SEALING CLAMP FOR PIPES

B-3.1 Simple pipe clamps with single plane lug plates are made from straight pieces of pipe, rolled plate, or piping elbows. They have lug or ear plates that are welded or formed on the sides in two pieces and then bolted together. Typically, the inside of the ear plate has grooves or channels formed with injection ports to inject the sealant. They are used on straight pipe or piping elbows. A straight pipe clamp is shown in Fig. 4 and Fig. 5.

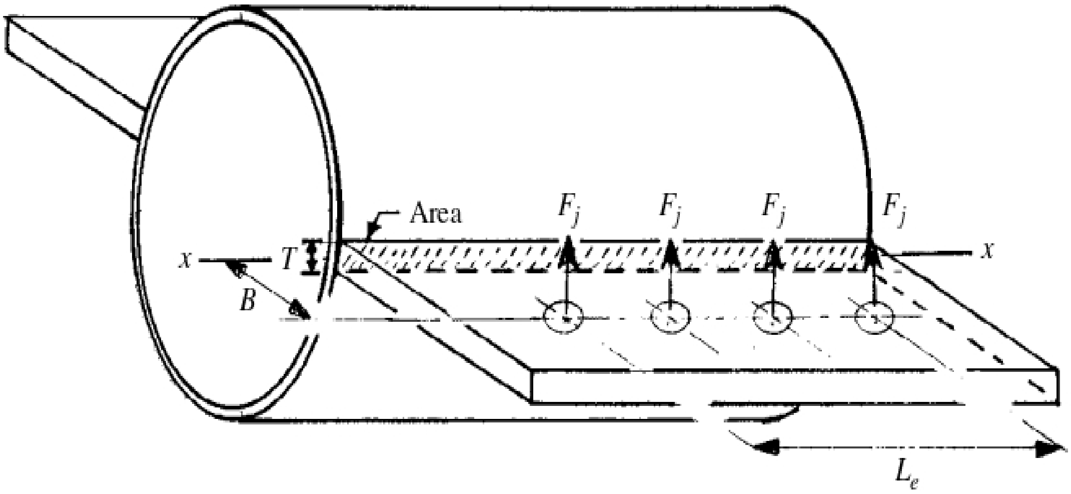

FIG. 4 STRAIGHT PIPE CLAMP

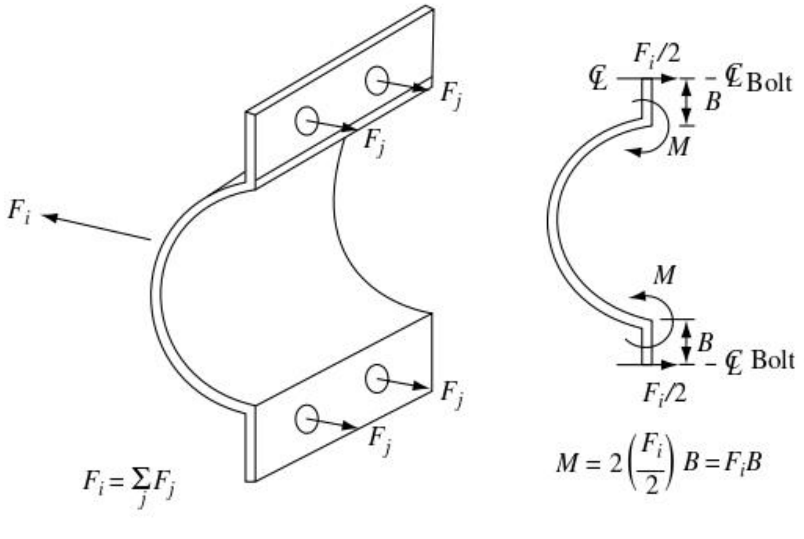

FIG. 5 BENDING MOMENT DUE TO FORCES IN STRAIGHT PIPE CLAMP

B-3.2 Calculation of Lug Plate Thickness

The shaded region in Fig. 4, marked ‘Area’, represents the area of intersection between the lug and clamp, which is in two pieces. Since the curvature of the area is very small at the lug plate-clamp intersection, it can approximate it as a rectangular area as shown in the Fig. 4. The reaction forces acting at the bolts, marked ‘Fj’, resist the clamp from being separated. These reactions induce a bending moment about the x-x axis as shown in the Fig. 4 and Fig. 5. The section modulus of the area is thus:

$$Z_A = \frac{L_e T^2}{6}$$

where

Z_A = section modulus, in mm^3;
L_e = effective length, in mm; length between bolt hole center lines on each end, (*see* Fig. 4); and
T = lug thickness, in mm (*see* Fig. 4).

Solving for the stress, we have

$$\sigma = \frac{M}{Z_A} = \frac{F_i B}{\frac{L_e T}{6}} = \frac{6 F_i B}{L_e T^2}$$

where

M = bending moment, in N-m;
F_i = summation of the forces acting on the bolts, in N; and
B = moment arm caused by the force F_j, in mm.

Referring to Fig. 6**,** the reaction force F_j is derived as follows:

$$h = R \sin\theta \quad (\textit{see} \text{ Fig. } 6)$$

where

R = internal radius of pipe.

$$\text{Area} = Gh = GR \sin\theta$$

where

G = inside depth of enclosure, in mm.

$$Fi = 2PGR \int_0^{\frac{\pi}{2}} \sin\theta \ d\theta = -2PGR \left[\cos\left(\frac{\pi}{2}\right) - \cos(0)\right]$$
$$= -2PGR(0\text{-}1) = 2PGR = PGD$$

$$Fi = \Sigma F_j = PGD \text{ (N)}$$

where

P = design pressure × C_{inj}, in N/mm; and
D = inside diameter of enclosure, in mm.

Solving for the required lug plate thickness,

$$T = \sqrt{\frac{6F_i B}{L_e \sigma}} = 2.45 \sqrt{\frac{F_i B}{L_e \sigma}}$$

Now from Fig. 7 and the lug thickness/calculation data, we have:

$$B = W\text{-}0.5 g_1$$
$$L_e = 2L_i \text{- } n d_B$$

where

n = number of bolt holes;
d_B = bolt hole diameter, in mm;
g_1 = sum of shell thickness and fillet weld length, in mm;
n = number of bolt holes;
F_i = forces due to injection, in N; and
L_i = distance between outermost bolt centers, in mm.

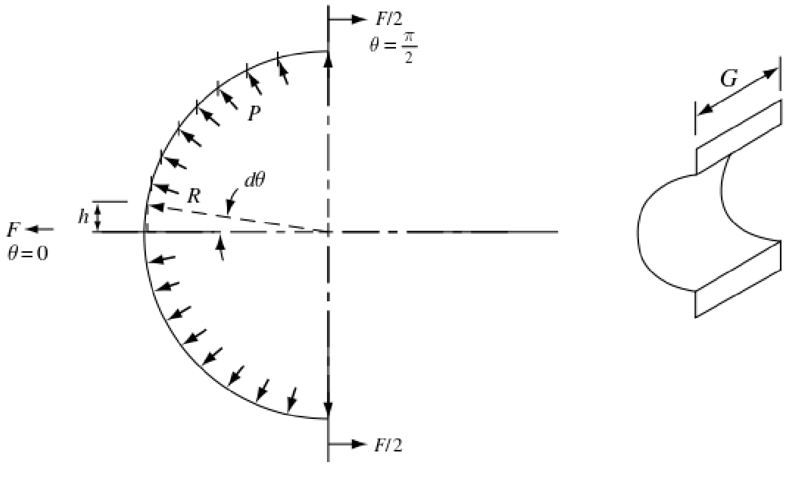

FIG. 6 LOADING FROM INTERNAL PRESSURE ON CLAMP WALL

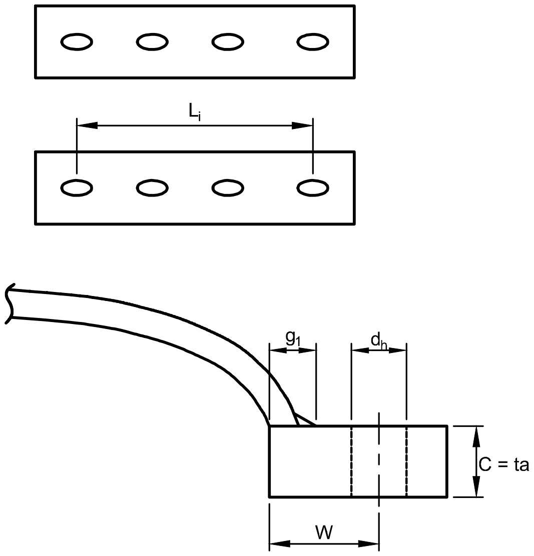

FIG. 7 DIMENSIONAL PARAMETERS ON CLAMP LUG PLATE

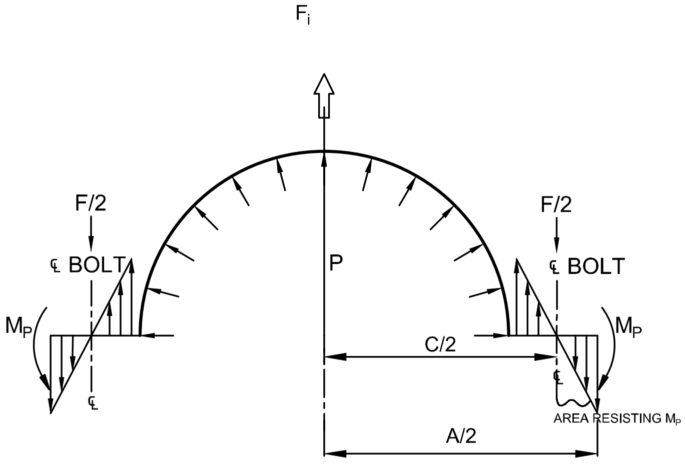

FIG. 8 BENDING MOMENTS AT LUG PLATE INCLUDING BY INTERNAL PRESSURE.

The term L_i is multiplied by two because there are two flanges (lugs), as detailed in Fig. 8. The term $2L_i$ is substituted by πC, for circular flanges (lugs), where C is the bolt circle diameter for two circular flanges.

Therefore, equation becomes,

$$T=2.45\sqrt{\frac{F_i\left(W\text{-}0.5g_1\right)}{(2L_i\text{-}\ nd_B)\sigma_a}}$$

where

σ_a = allowable stress at design temperature of luge material, (in MPa)

B-3.3 Calculation of Number of Bolts

The required bolt area is:

$$A_B=\frac{\left[H+\dfrac{2M_p}{(A\text{-}C)}\right]}{\sigma_a}$$

where

M_p = $(\mathrm{F_i}/2)(\mathrm{C}/2)$, (*see* Fig. 8**)**, in N-mm;
H = hydrostaid end force on area inside of flange (same as F_i), in *N;*
A = outside diameter of flange, in mm; and
C = bolt circle diameter (for circular flange), in mm.

Referring to Fig. 8, the part of the lug, or ear, that is in compression from the moment M_p is $(A-C)/2$. This is the effective area that is resisting the bending moment. The equation above applies for circular flanges. Rewriting the equation for straight flange, we solve for the total bolt area as:

$$A'_B=\frac{\left[F_i+\dfrac{2M_p}{2L_i+(A\text{-}C)}\right]}{\sigma_a}$$

Thus, the number of bolts required, *n*, is:

$$n = A'_B/A_B$$

ANNEX C

(*Clause* 4.3.3)

METHOD OF TEST FOR TGA ANALYSIS OF SEALING COMPUND

C-1 APPARATUS

C-1.1 Thermo gravimetric analyser.

There are many types of analyser commercially available but their suitability should be checked using the procedure to operate the thermo gravimetric analyser in accordance with the manufacturer's instructions.

C-1.2 The basic components of an analyser are as follows:

C-1.2.1 Thermo gravimetric balance.

C-1.2.2 Electrically heated, thermo-regulated oven.

C-1.2.3 Temperature programmer, for the oven.

C-1.2.4 Switching device, allowing a stream of nitrogen or a stream of air or oxygen (or a mixture of nitrogen and air or oxygen) to flow through the oven at a predetermined and constant flow rate.

C-1.2.5 X/Y recorder, for recording the temperature/mass plot. Alternatively, temperature/time plots may be recorded simultaneously using a two-pen Y/T recorder.

C-2 TEST PROCEDURE

Because of the different rubbers & blends including vulcanizes are designed in the compound's formulation, it will need to set the temperature and time scale required based on type of compound and its maximum operating temperature. In TGA analysis to determine percentage loss, analyst to proceed with the following method or to make appropriate modifications to suit the requirement.

C-2.1 Place a test portion of compound sample (average weight 22 g), in the thermo balance sample pan and heat to 50 °C and keep the sample at this temperature for 10 minutes in a stream of nitrogen at the maximum rate allowed by the programmer.

C-2.2 Increase the temperature to 100 °C and maintain it for 2 h introducing air or oxygen and allow the test sample to get heated uniformly.

C-2.3 When there is no further mass change, increase to next higher temperature in multiple 100 °C for 2 h where maximum operating temperature of compound (*see* Table 2) is up to 400 °C and for operating temperature above 400 °C, increase will be in multiples of 200 °C to 300 °C for 2 h so that finally it will be kept for 4 h at maximum operating temperature as compound will be stable in the last stage.

C-2.4 Observe the thermo-gravimetric analyser mass trace when this no longer indicates a mass loss with time.

C-3 EXPRESSION OF RESULTS

The percentage loss in weight is calculated by the formula:

$$\text{Percentage loss in weight} = \frac{m_1 - m_2}{m_1} \times 100$$

where

m_1 = mass of the test portion, in mg; and
m_2 = mass indicated at the end if the heating period of total 8 h, in mg.

ANNEX D
(*Foreword*)

COMMITTEE COMPOSITION

Fluid Power System Sectional Committee, PGD 36

Organization	*Representatives(s)*
L&T Construction Limited, Bengaluru	Shri Shiva Shankar (***Chairperson***)
Ace Designers Limited, Bengaluru	Shri T. P. Sridhar
BEML Limited, Bengaluru	Shri A. Subramanyam Shri V. Sekar (*Alternate* I) Shri S. Basavaraju (*Alternate* II)
Bosch Rexroth Indian Limited, Ahmedabad	Shri Mukesh Dodiya Shri Prashant Katkar (*Alternate*)
Central Institute of Tool Design, Hyderabad	Shri Shujayat Khan
Central Manufacturing Technology Institute, Bengaluru	Dr Nagahanumaiah Shri S. K. Verma (*Alternate*)
CSIR - National Aerospace Laboratories, Bengaluru	Shri Thennavarajan S.
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Festo India Private Limited, Bengaluru	Shri R. Joshi Shri P. Shah (*Alternate*)
Fluid Power Society of India (FPSI), Bengaluru	Dr Prasanna Kumar Shri M. Yoganarsimha (*Alternate*)
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Scientist ‘B’/Assistant Director
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Panel on Online Leakage Sealing Systems

Organisation	*Representative (s)*
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ONGC Petro Additions Ltd, Dahej	Shri Rajindra Patil
Quest Global Engineering Services Pvt Ltd, Banglore	Shri Anshuman Sehgal
Reliability Static, Reliance Industries Ltd, Jamnagar	Shri Anand Umakanthan
Vidarbha Industries Power Ltd, Reliance Power, Butibori, Nagpur	Shri Rajendra Kale

(*Continued from second cover*)

A516/A516M – 17 : 2017	Standard specification for pressure vessel plates, carbon steel, for moderate and lower-temperature service
A387/A387M – 17a : 2017	Standard specification for pressure vessel plates, alloy steel, chromium-molybdenum
A106/A106M – 18 : 2018	Standard specification for seamless carbon steel pipe for high-temperature service
A335/A335M – 18b : 2018	Standard specification for seamless ferritic alloy-steel pipe for high-temperature service
A193/A193M – 17 : 2017	Standard specification for alloy-steel and stainless steel bolting for high temperature or high pressure service and other special purpose applications
A194/A194M – 17a : 2017	Standard specification for carbon steel, alloy steel, and stainless steel nuts for bolts for high pressure or high temperature service of both

The composition of the committee, responsible for the formulation of this standard is listed in Annex D.

For the purpose of deciding whether a particular requirement of the new standard is complied with, the final value, observed or calculated, expressing the result of a test shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding of numerical values (*second revision*).' The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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